Intertidal Habitats

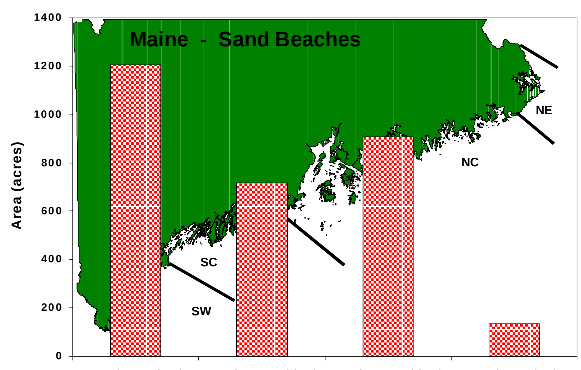
Functions and Values of Sand Beaches:

What are Sand Beaches?

Sand beaches are dynamic unstable high energy marine environments. Sand beaches are composed of fine quartz sands derived from glacial deposits and discharged from rivers and streams. In the southern portion of the state a majority of the sediments come from the Saco River (Kelley et al. 1989). Additional sediments wash ashore from off-shore subtidal basins (Fefer et.al 1980). Daily and seasonally sands are shifted in the surf by wind, waves and currents. Gentle wind and wave action deposit sands onto beaches and dunes in the summer. Storms remove sands from the beaches in the winter dramatically altering the slope of the beach. Longshore transport currents, carry sediments up and down the coast constantly overturning sediments.

Where are Sand Beaches Located In Maine?

There are approximately 3,000 acres of sand beach on the coastal mainland and offshore islands in Maine. Sand beaches only total 2 % of all intertidal habitats in Maine. Of that 2 %, 40 % of all sand beaches is located on the southern coast south of Casco Bay. The concentration of southern beaches is between Kittery and Cape Elizabeth.



Twenty-four percent of the sand beaches statewide is located within Casco Bay and Muscongus Bay. In contrast to the southern coastal landscape, the longest stretches of beach along the south-central coast are only located at Popham Beach and Sewell Beach in Phippsburg, Reid State Park in Georgetown and Pemaquid Beach in New Harbor. Large sand beaches become rare as one travels east. Small pocket beaches can be found at Owls Head, Acadia National Park, Lincolnville, Roque Island, Sandy River in Jonesport, and within the St. Croix River estuary.

What are the Functions of Sand Beaches?

Sand beaches support a high population of small invertebrates, bacteria and algae specially adapted to thrive in a constantly shifting environment. Bacteria, diatoms, and blue-green algae live in between sand grains and provide food for microscopic protozoans, crustaceans, invertebrate larvae and roundworms (Berrill and Berrill 1981). Low intertidal zones of sand beaches, which are protected from extreme heat and freezing temperatures, have high concentrations of small invertebrates (e.g., amphipods, isopods, clams, polychaete worms, oligochaete worms, cumaceans) important for food chain interactions (Larsen and Doggett 1990). These zones are essential foraging areas for gulls, terns and 23 other species of migrating shorebirds (Brown 1993; USF&W 1980). Amphipods, also known as beach-hoppers, living in the high intertidal wrack line, break down organic plant matter and provide additional food for shorebirds.

Sand beaches function as critical resting sites for shorebirds during their long northerly and southerly migration. They are roosting habitat for at least 19 species of shorebirds (USF&W 1980).

The endangered species, piping plover and least tern, nest and breed on sand dunes above the high intertidal zone of sand beaches between May and August. Beaches are wintering habitat for purple sandpipers (USF&W 1980).

What are the Economic and Recreational Values of Sand Beaches?

Sand beaches in southern coastal townships are an important recreational area for residents and tourists. Long stretches of sand beaches support an entire tourism industry based on swimming, sun bathing and relaxation. Small towns, like Old Orchard Beach, rely on the natural beauty and benefits that sand beaches provide to encourage tourism and commerce within their region. The aesthetic allure of sand beaches and high energy surf raises the value of commercial and private shorefront property.

Commercially harvested species of soft-shelled clams, surf clams (in the shallow subtidal), blood worms, sand worms, and periwinkles are found in low abundance on some sand beaches.

How Sensitive are Sand Beaches to Disturbance and Development?

Sand beaches have different classifications based on their intertidal zonation (see Habitat Rankings). Low intertidal areas are ranked by the Dept. of Environmental Protection as having a high sensitivity to development and disturbance. They are areas containing high concentrations of small invertebrates that are essential food for migrating shorebirds. Mid and high intertidal areas are classified as high to moderately sensitive to disturbance. Heavy wave and current action, mixing sands, and high exposure to wind, rain, freezing temperatures and sunlight make these intertidal zones less productive and diverse. However, endangered species such as piping plovers live and breed in high intertidal habitats raising the habitat value of some locations.

Sand beaches, due to the high wave energy, can recover relatively quickly from low impact activities like jogging or digging.

What are the Threats to Sand Beaches?

- Dredging, dragging, scraping, or other major physical disturbances: Disturbances can liberate toxics and nutrients from sediments into the water column. Channel dredging and scraping removes sediments, which may lead to increased coastal erosion and loss of breeding habitat for shorebirds.
- Disturbance of nest sites: Shorebirds, like the endangered piping plover, nest and feed on sand beaches in the spring and summer. Any major or minor disturbance (e.g. walking on the beach) can cause them to abandon the nest.
- Seawalls and other shoreline stabilization barriers (e.g., rip-rap): As sea levels rise, physical barriers prevent the intertidal region from extending landward decreasing the acreage of intertidal habitat.
- Other physical barriers: Any structures (e.g., groin, dam, culverts, bridge) that change current or tidal flows or direction, alter salinity, disrupt travel corridors for animals, modify drainage of the beaches, increase scour, prevent sediment movement and larval and fish passage threaten the survival of sand beaches.
- Sediment disposal: Disposal of any sediments or other material smothers plant and animal life.
- Water Quality Alterations: Any change in the salinity, temperature, turbidity, or physical properties of the water will negatively affect sand beaches. Pollutants from point and non-point sources can change communities of infauna and epifauna.
- Cumulative impacts: Over-development of areas adjacent to sand beaches reduces acreage of unspoiled beaches; reduces drainage areas; attracts more people to the coast; increases disturbance, erosion and stormwater run-off; reduces public access; leads to additional armoring of the shore and threatens wildlife.
- Pipe laying: Loss of sand beach habitat under the pipe and the potential impact from any waste discharged from the pipe. Depending on the size of the pipe, it may also interfere with the natural movement of sand.

What are the Permitting Issues of Sand Beaches?

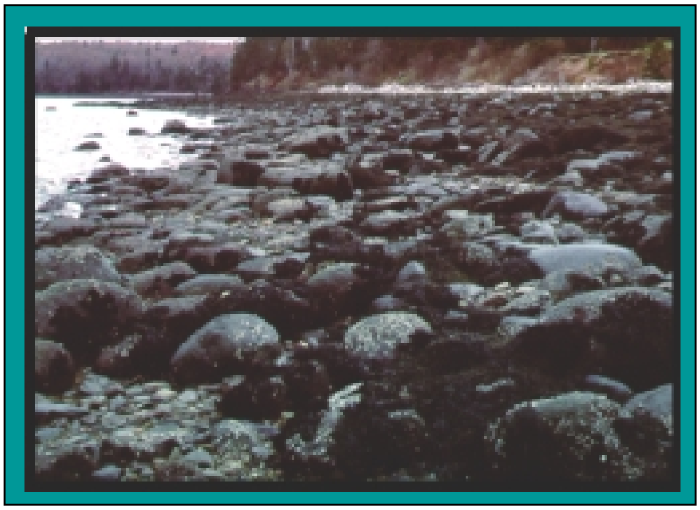
- Disturbance on sand beaches should be avoided during spring and fall shorebird migrations and during the breeding season (late spring and summer). The fall, due to the migratory flight pattern, is more important than the spring. Spring migration is between mid-April and early June. Fall migration is between July and November (USF&W 1980).
- Shoreline development, discharges of freshwater or pollutants, or disturbance should be minimized in or around sand beaches. No filling should be permitted without proper compensation.
- Dredging should be avoided or managed in a careful manner. Chemical sediment analysis, dredge disposal sites and geological processes should be evaluated before permitting any activity.
- Physical barriers should only be permitted in emergency situations. Sediment movement and transport must be mapped before licensing any structure. Barriers should never extend into the subtidal.

- New developments in the adjacent upland should maintain pre-development levels of ground water seepage and eliminate increases of stormwater runoff.

Summary of the Functions and Values of Sand Beaches.

Functions	Values
1. Production of animals on and within the sand	Essential foraging habitats for migrating shorebirds Supports the food web Supports commercial fisheries
2. Recreational	Supports multi-million dollar tourism industry Aesthetically pleasing High recreational and educational value
3. Essential habitat for birds	Foraging, roosting and staging areas for migrating shorebirds, gulls and terns Wintering areas for purple sandpipers
4. Primary production from benthic diatoms and blue-green algae	Improves water quality Binds sediments therefore reducing erosion Fuels benthic food web Supports commercial fisheries and wildlife
5. Recycling of nutrients by bacteria	Supports plant and algal growth Supports commercial fisheries
6. Rare plant and animal habitat	Nesting and feeding ground for endangered piping plovers and least tern Rare plant habitat

Functions and Values of Boulder Beaches:

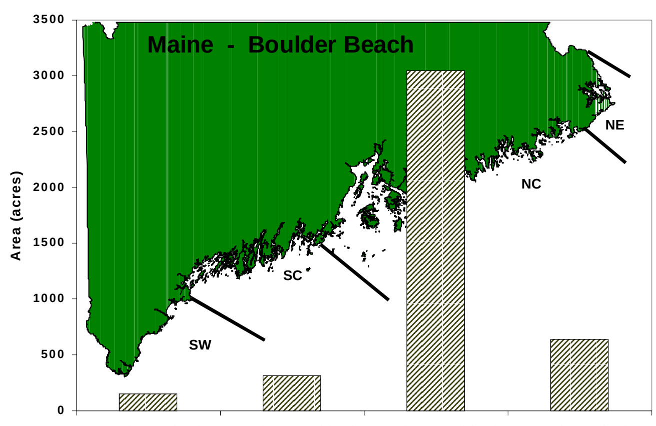


What are Boulder Beaches?

Boulder beaches and boulder ramps are partially exposed beaches that are primarily composed of round boulders between 10 inches and 10 feet in diameter. The boulders are large enough to resist being over turned by wave action. Many of the beaches lie adjacent to ledge outcrops. Boulder beaches were formed by glacial scouring and deposition and bedrock erosion. In areas that receive a high degree of direct wind and wave expose from the Gulf of Maine, the weathering of the granite ledges slowly resupplies the beaches with additional boulders. Underneath each boulder lies a thick layer of coarse and fine sediments for infaunal communities.

Where are Boulder Beaches Located in Maine?

Boulder beaches are scarce marine habitats in Maine. Less than 3 % (4,150 acres) of all the intertidal shoreline in Maine is composed of boulders with over 27 % of the acreage located on offshore islands. Approximately 90 % of the beaches is located within and north of Penobscot Bay. The largest deposits are found in Rockland, Brooklin, Barlett Island and Swan Island. Smaller deposits are located on Bailey Island, Monument Cove on Mt. Desert Island, Lincolnville and West Quoddy Head St. Park.



What are the Functions of Boulder Beaches?

Boulder beaches are one of the most diverse intertidal habitats (Larsen and Doggett 1981). The boulder fields function as a stable environment for the attachment of algae and organisms. Animals seek shelter underneath the boulders, within the coarse and fine sediments and within and underneath the covering of kelps, rockweeds, and Irish moss (see rockweed and kelp for additional functions). Primary production from macroalgae is high as well as secondary production from epifauna and infauna. Polychaete worms, oligochaete worms, flatworms, clams, amphipods, isopods, crabs, roundworms, ribbon worms, scaleworms, limpets, barnacles, periwinkles and dog winkles all colonize boulder beaches. These small organisms feed fish and birds and contribute to the biodiversity of the marine ecosystem. Unique intertidal species such as sea spiders, spider crabs, brittle stars, sea cucumbers and nudibranchs (sea-slugs) that are sensitive to environmental and anthropogenic influence are found in low intertidal zones on boulder beaches. Small fish such as the rock gunnels and sculpins forage and seek shelter on boulder beaches (Brown 1993). Boulder beaches export plant and animal detritus to offshore and upper intertidal communities for microbial food webs. Boulder beaches intercept large sea swells and slow shoreline erosion.

Boulder beaches are foraging habitat for eight species of shorebirds, waterfowl and gulls. They also function as roosting habitat during long migrations for ten species of shorebirds (USF&W 1980).

Purple sandpipers use boulder beaches as wintering habitat (USF&W 1980).

What are the Economic Values of Boulder Beaches?

Boulder beaches contribute to the production of commercial species such as lobsters, blue mussels, periwinkles and sea cucumbers. Low intertidal zones function as nursery grounds for juvenile lobsters and foraging habitat for fish during high tide. Ascophyllum, Irish moss and kelp is sometimes harvested from boulder beaches.

How Sensitive are Boulder Beaches to Disturbance and Development?

Boulder beaches have three DEP sensitivity classifications for three different intertidal zones (see Habitat Rankings). Low intertidal zones of boulder beaches with algal cover have high species diversity and support species not found commonly in other intertidal habitats. These areas have been classified as highly sensitive to disturbance. Mid intertidal zone with no algae are less diverse and have fewer commercial and ecological functions; therefore they are classified as moderately sensitive to disturbance. Dry, exposed, barren high intertidal boulder beaches support few intertidal species. These areas can recover from physical activities and are therefore classified as having a low sensitivity to disturbance and development.

What are the Threats to Boulder Beaches?

- <u>Shading from physical structures</u>: Shading blocks light and reduces algal growth.
- <u>Removal and/ or disturbance of habitat</u>: Dredging, removal of boulders, impoundment of water and sediment loading smothers or removes boulder habitat. Loss of boulders equals a loss of shelter and feeding areas for animals.
- <u>Pollution</u>: Run-off of sediments and pollutants from upland construction sites, increases in freshwater discharge, industrial discharges, oil pollution, stormwater run-

off, sewage, airborne pesticides from agriculture and others all damage boulder beaches. In addition, phytoplankton blooms caused by nutrient loading from pollution cause reductions in light levels harming algal beds on boulders.

- Resuspension of sediments: Resuspension of sediments from dredging, filling, boating and fishing activity smother boulder habitat. Resuspension of sediments may resuspend larvae and small invertebrates changing the community structure of the habitat and endangering algal beds.

What are the Permitting Issues of Boulder Beaches?

- Avoid permitting activities that remove boulders or shade environments.
- Avoid permitting activities in the low intertidal and shallow subtidal.
- Permit activities in high intertidal zones and mid intertidal zones without algae cover.
- Water dependent structures should be placed in areas that will not shade algae or indirectly impact algal beds. If unavoidable, structures should be as narrow as possible, as high as possible and oriented as close to north-south as possible (see eelgrass for guidelines). Avoid permitting activities where boat traffic can shade beds associated with boulders.
- Consider removing boulders and any associated lobsters and placing them in adjacent habitats before construction.
- Avoid sediment disposal on or around boulder beaches. Avoid activities that will resuspend sediments around algal beds.
- If applicable, determine if current velocity, tidal flows, wave energy or water clarity will be altered due to the proposed activity. If so, design project to minimize physical changes.
- Discharges of freshwater or pollutants should be minimized around boulder beaches.
- New developments in the adjacent upland should maintain pre-development levels of ground water seepage and eliminate increases of storm water runoff.

Summary of the Functions and Values of Intertidal Boulder Habitats.

Functions	Values
1. Production of animals on rocks, under rocks, in sediments under boulders, on and within algal beds	Supports commercial fisheries Supports the food web Supports recreational sport fishery Support shorebirds, seabirds, and sea ducks
2. Permanent and stable attachment sites for primary producers (see kelp / rockweed)	Food resources for consumers Support commercial fisheries and wildlife Commercially harvested for food and nutrients
3. Roosting sites and wintering habitat for birds	Helps sustain healthy populations of shorebirds, sea birds, and sea ducks
4. Intercepts and slows currents and waves	Reduces shoreline erosion of nearshore habitats Increases sedimentation
5. Nursery and spawning ground	Promotes and sustains lobster populations Helps sustain mussel populations Maintains balanced ecosystem
6. Nutrient and contaminant filtration	Improves water quality Supports commercial fisheries
7. Oxygen production	Provides oxygen for marine organisms Improves water quality Supports commercial fisheries
8. Production, accumulation and export of detritus	Fuels microbial, estuarine and offshore food webs Supports commercial fisheries
9. Recycling of nutrients	Supports plant and algal growth Supports commercial fisheries
10. Self-sustaining ecosystem	Increases marine biodiversity Forms numerous and complex microhabitats Supports tourism industry

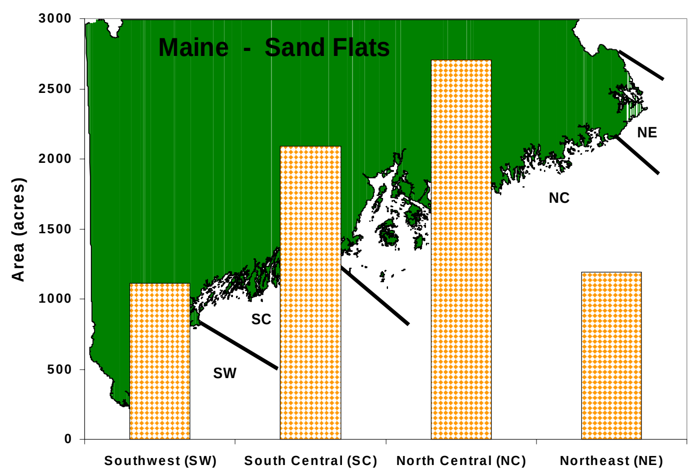
Functions and Values of Sand Flats:

What are Sand Flats?

Sand flats, like mud flats, are sensitive habitats sheltered by rocky headlands, islands, and sand barriers. Most sand flats are located in coves, bays and estuaries. They receive greater wave energy and tidal currents than mud flats preventing the fine silt and clays from settling out of the water column. Only the larger sand grains and organic detritus remain on the intertidal flats (some sand flats may have a small portion of silts and clays mixed with sand). Sand flats can be distinguished from mud flats by the coarser nature of the sediment as well as the sand waves that appear on the surface during ebb tide (see photo above). They receive sediments from the same sources as mud flats.

Where are Sand Flats Located in Maine?

Sand flats are scarce in Maine. Only 5 % of the shoreline of Maine is sand flats. Eight-five percent of the 7,102 acres of sand flat is located north of South Portland. The largest sand flats are found in Sagadahoc Bay and Heal Eddy, Georgetown; Gerrish Island, Kittery; Bailey's Mistake, Trescott; and Clam Cove, Rockport (Larsen and Doggett 1981).



What are the Functions of Sand Flats?

Sand flats support large populations of filter feeders, sediment deposit-feeders, grazers, and predatory worms and crustaceans. In comparison with other intertidal habitats, sand flats have the second highest mean species diversity (Larsen and Doggett 1981). Sand flats, like mud flats, are marine sediment soups of microscopic algae, bacteria, and animals contributing to primary and secondary productivity, organic breakdown, nutrient recycling, and scour reduction. Large populations of amphipods, polychaete worms, clams, oligochaete worms, round worms, isopods, cumaceans, bivalves, crabs, Capitellid worms, sand shrimp, hydrobia snails, dog whelks, moon snails and hermit crabs settle, forage and breed on intertidal sand flats (Brown 1993; Larsen and Doggett 1981). Often flats are colonized by eelgrass and their associated fauna and flora (see Eelgrass). Mummichogs, sticklebacks, silversides and other small fish feed on flats during high tide. They are nursery grounds for finfish, sand shrimp, clams and other invertebrates. Like mud flats, sand flats slow tidal and wave energy buffering the upland against tidal erosion and lessening impacts from storm surge events.

Sand flats are critical feeding areas for 24 species of migrating shorebirds, waterfowl, wading birds and gulls. Sand flats are roosting and resting sites for 19 species of shorebirds (USF&W 1980).

What Are the Economic Values of Sand Flats?

Sand flats contain commercially important populations of sand worms, blood worms, sand shrimp, periwinkles, blue mussels, quahogs, razor clams and soft-shelled clams that were valued at over $11 million upon landing in 1997 (NOAA 1997).

In addition tidal sand flats are foraging areas for commercially and recreationally important species such as winter flounder, Atlantic herring, rainbow smelt, alewife, and Atlantic mackerel valued at over $ 8 million upon landing in Maine in 1997 (Brown 1993; Whitlatch 1982; NOAA 1997).

How Sensitive are Sand Flats to Disturbance and Development?

Based on their high commercial and ecological values and their slow recovery rates from physical disturbance, sand flats are classified by DEP as a high sensitivity habitat (see Habitat Rankings).

What are the Threats to Sand Flats?

- <u>Filling of sand flats:</u> Filling results in a direct loss of intertidal habitat.
- <u>Dredging, dragging or other major physical disturbances</u>: Disturbances can liberate toxics and nutrients from sediments into the water column. Dredging removes habitat that can lead to increases in coastal erosion. Dragging kills epifauna and encourages the spread of opportunistic species.
- <u>Sediment disposal:</u> Disposal of any sediments or other material smothers plant and animal life.
- <u>Seawalls and other shoreline stabilization barriers (e.g. riprap):</u> Sand flats require continual sources of sediments from upland and coastal erosion. Without renewable resources of fine grain sediments entering these regions, surface layers of sand flats will erode leaving behind hard clays and altering the species composition and productivity of the flat. Also, as sea levels rise, physical barriers prevent the intertidal region from extending landward decreasing the acreage of intertidal habitat.
- <u>Water Quality Alterations:</u> Any change in the salinity, temperature, turbidity, or physical properties of the water will negatively affect sand flats. Pollutants from point and non-point sources can change communities of infauna and epifauna.

- Lobster pound creation / Impoundment of water: impoundments convert intertidal areas into subtidal areas by changing the hydrologic system. This leads to the loss of fine sediments and rockweed, and the reduction of species diversity within the benthic and algal communities.
- Other physical barriers: Any structures (e.g. groin, dam, culverts, bridge) that change current or tidal flows or directions, alter salinity, disrupt travel corridors for animals, modify drainage of the flats, prevent sediment movement and larval and fish passage threaten the survival of sand flat communities.
- Pipe laying: Loss of habitat under the pipe and the potential impact from any waste discharged from the pipe.

What are the Permitting Issues of Sand Flats?

- Shoreline development, discharges of freshwater or pollutants, or disturbance should be minimized in or around sand flats. No filling of sand flats should be permitted without proper compensation. Large machinery should not be allowed on sand flats.
- Dredging should be avoided or managed in a careful manner. Chemical sediment analysis, dredge disposal sites and geological processes should be evaluated before permitting any activity.
- Physical barriers should only be permitted in emergency situations. They should never extend into the subtidal.
- Coastal development on the upland should be restricted around flats. Plan for future sea level rise and allow for ample landward migration of sand flats.
- New developments in the adjacent upland should maintain pre-development levels of ground water seepage and eliminate increases of stormwater runoff.
- Disturbance on sand flats should be avoided during spring and fall shorebird migrations. The fall, due to the migratory flight pattern, is more important than the spring. Spring migration is between mid-April and early June. Fall migration is between July and November (USF&W 1980).

Summary of the Functions and Values of Sand Flats (adapted from Short, F.T. et al. 1999).

Functions	Values
1. Production of animals on and within the mud or sand	Supports commercial species Food for fish, crab, shrimp, and other invertebrates Essential food resources for migrating shorebirds Supports the food web
2. Primary production from benthic diatoms and algae	Improves water quality Binds sediments therefore reducing erosion / resuspension Fuels benthic food web Supports commercial fisheries and wildlife
3. Recycing of nutrients by bacteria	Supports plant and algal growth Supports commercial fisheries
4. Sediment sink and trap	Improves water quality (removes nutrients and toxics) Lessens coastal erosion
5. Essential habitat	Provides the soil for eelgrass germination and proliferation Nursery ground for commercially important fish Roosting and staging areas for migrating shorebirds

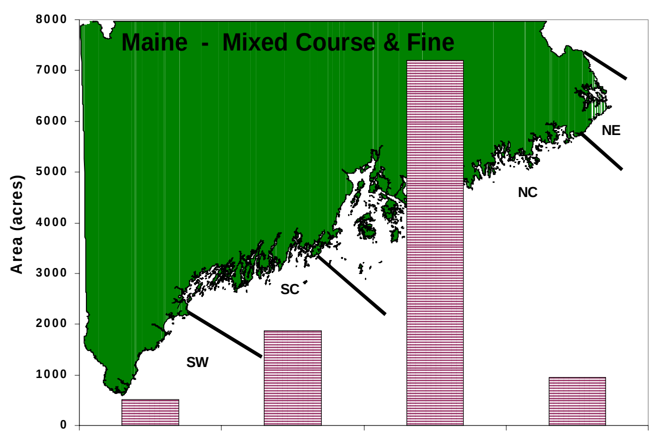
Functions and Values of Mixed Coarse and Fine Flats:

What are Mixed Coarse and Fine Flats?

Mixed coarse and fine flats are intertidal flats with a mixture of gravel, cobble, boulder, sand, shell, organic detritus, silt and clay sediments. Due to the large number of attachment sites on the rocks, these flats are characteristically covered in rockweed or other macro algae. Low intertidal areas may have Irish moss or patches of kelp attached to larger cobbles and boulders. The wave energy can vary depending on the location of the flat. Exposed sites with an unlimited fetch will have a greater percentage of coarse-grained sediments. Protected mixed coarse and fine flats will have a higher percentage of fine clays, silt and sand. Mixed flats are unstable environments where rocks, sediments and associated fauna are tossed around during heavy wave action.

Where are Mixed Coarse and Fine Flats Located in Maine?

There are 10,530 acres of mixed coarse and fine intertidal flats in Maine. Twenty percent of the total acreage is located on offshore islands. Most of the mixed flats are located in the north-central portion of the state from Penobscot Bay to Machias Bay. Less than 5 % of the mixed flats are found south of Portland. Most of the far southern flats are located near Kittery, Biddeford Pool and Wells. In the south-central portion of the state a majority of the mixed flats, totaling 1,022 acres, are situated between Portland and Bailey Island. Jonesport (371 acres), Machias Bay (525 acres) and Eastport (422 acres) have the largest area of mixed coarse and fine flats statewide.



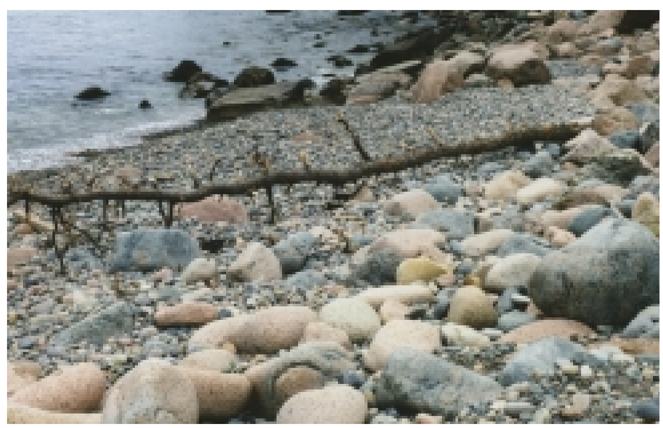
What are the Functions of Mixed Coarse and Fine Flats?

Mixed coarse and fine flats have similar functions as sand flats and mud flats however they usually support fewer numbers of animals and are less biologically diverse. Mixed flats support populations of benthic algae, bacteria, and small invertebrates that contribute to the health of the marine ecosystem. Snails, amphipods, isopods, polychaete and oligochaete worms, nematodes, earwigs, barnacles, limpets, moon snails, nudibranchs, small clams , hydroids, dog winkles, and hermit crabs, sand shrimp, oysters, and tube worms live in or on mixed coarse flats in Maine (Larsen and Doggett 1981). Macro-algae and eelgrass and their associated fauna and flora often colonizes mixed flats increasing the functions and values of the habitat (see Rockweed and Eelgrass). Small fish like mummichog and sticklebacks that are prey to top consumers, forage during flood and ebb tides. Amphipods, also known as beach-hoppers, living in the high intertidal wrack line, break down organic plant matter and provide food for birds. Mixed coarse and fine flats are foraging habitat for 24 species of shorebird, American black ducks, great blue herons, and wading birds, terns and gulls (USF&W 1980).

Mixed flats function as roosting habitat for 19 species of shorebirds (USF&W 1980).

Between April and June, these flats are nesting sites for spotted sandpiper. In the winter, purple sandpiper live on mixed flats (USF&W 1980).

Gravel beaches and cobble beaches, classified under mixed coarse and fine flats for this report, have fewer numbers of species as mixed flats. Gravel and cobble beaches are less protected from sea swells and have only a small percentage of fine grained sediments. Most are completely unvegetated. Cobble and gravel are constantly rolled by waves creating an environment that only few species can colonize. The diversity is lower but the production of the few adaptive species such as oligochaete, flat, and nemertean worms, is often high.



Cobble beach near Seal Harbor, Mt. Desert Island.

What are the Economic Values of Mixed Coarse and Fines?

Mixed coarse and fine flats are heavily harvested in Maine for soft-shelled clams, sand worms, and blood worms. Mixed flats also support populations of lobsters, quahogs, periwinkles, blue mussels, Irish moss, knotted wrack, kelp, rock crabs, and mud shrimp (Brown 1993). Mixed flats contributed to landings valued at over $150 million in 1997 (NOAA 1997).

Lobsters nursery grounds are located in low intertidal zones. Juveniles live under cobbles and boulders. The greatest population density in the intertidal area is between May and November. Adult lobsters, greater than 6 years old, move offshore in the winter while juveniles remain in low intertidal rocky environments. Adults return to the intertidal habitat in the late spring and summer (Diane Cowan, personal comm.).

How Sensitive are Mixed Coarse and Fines to Disturbance and Development?

The ecological sensitivity of mixed coarse and fine environments depends on the location within the intertidal zone. Low intertidal zones are classified by DEP as having a moderate to high sensitivity to disturbance (see Habitat Rankings). These areas are lobster nursery grounds and regions of high abundance and diversity of fauna. However, mid and high intertidal zones, with no red or brown algae, are classified as low sensitivity. These areas have fewer functions and values and support small populations of opportunistic species.

What are the Threats to Mixed Coarse and Fines?

- <u>Filling of flats:</u> Filling results in a direct loss of intertidal habitat.
- <u>Dredging, dragging or other major physical disturbances</u>: Disturbances can liberate toxics and nutrients from sediments into the water column. Dredging removes habitat that can lead to increases in coastal erosion.
- <u>Sediment disposal:</u> Disposal of any sediments or other material smothers plant and animal life.
- <u>Seawalls and other shoreline stabilization barriers (e.g. rip-rap):</u> Flats require continual sources of sediments from upland and coastal erosion. Without renewable resources of fine grain sediments entering these regions, surface layers of mixed flats will erode leaving behind hard clays and altering the species composition and productivity of the flat. Also, as sea levels rise, physical barriers prevent the intertidal region from extending landward decreasing the acreage of intertidal habitat.
- <u>Water quality alterations:</u> Any change in the salinity, temperature, turbidity, or physical properties of the water will negatively affect mixed environments. Fresh water discharges especially impact lobster nursery grounds. Pollutants from point and non-point sources can change communities of infauna and epifauna.
- <u>Lobster pound creation / Impoundment of water</u>: Lobster pounds converts intertidal area into subtidal area by changing the hydrologic system. This leads to the loss of fine sediments and rockweed, and the reduction of species diversity within the benthic and algal communities.
- <u>Other physical barriers:</u> Any structures (e.g. groin, dam, culverts, bridge) that change current or tidal flows or directions, alter salinity, disrupt travel corridors for animals, modify drainage of the flats, prevent sediment movement and larval and fish passage threaten the survival of animals in mixed environments.

- Pipe laying: Laying of pipe leads to the loss of habitat under the pipe and the potential impact from any waste discharged from the pipe.

What are the Permitting Issues of Mixed Coarse and Fines?

- Shoreline development, discharges of freshwater or pollutants, or disturbance should be minimized in or around flats. No filling of mixed coarse flats should be permitted without proper compensation. Large machinery should not be allowed on lower intertidal regions of mixed flats.
- If feasible, restrict activity to upper intertidal shores or unvegetated mid intertidal zones.
- Choose to disturb unvegetated gravel or cobble beaches over finer more diverse mixed flats.
- Dredging should be avoided or managed in a careful manner. Chemical sediment analysis, dredge disposal sites and geological processes should be evaluated before permitting any activity.
- Physical barriers should only be permitted in emergency situations. They should never extend into the subtidal.
- Coastal development on the upland should be restricted around flats. Plan for future sea level rise and allow for ample landward migration of mixed flats.
- New developments or activities in the adjacent upland should maintain pre-development levels of ground water seepage and eliminate increases of storm water runoff to flats. Fresh water will kill juvenile lobsters and marine fauna.
- Disturbance on mixed coarse and fines should be avoided during spring and fall shorebird migrations. The fall, due to the migratory flight pattern, is more important than the spring. Spring migration is between mid-April and early June. Fall migration is between July and November (USF&W 1980).

Summary of the Functions and Values of Mixed Coarse and Fine Flats (adapted from Short, F.T. et al. 1999).

Functions	**Values**
1. Production of animals on and within the sediment and under rocks	Supports commercial shellfish and worm fishery Supports lobster fishery Food for fish, crab, shrimp, and other invertebrates Essential food resources for migrating shorebirds Supports the food web
2. Primary production from benthic diatoms and algae	Improves water quality Binds sediments therefore reducing erosion Fuels benthic food web Supports commercial fisheries and wildlife
3. Recycing of nutrients by bacteria	Supports plant and algal growth Supports commercial fisheries
4. Sediment sink and trap	Improves water quality (removes nutrients and toxics) Lessens coastal erosion
5. Essential habitat	Provides the soil for eelgrass germination and proliferation Nursery ground for commercial fish and lobsters Roosting and staging areas for migrating shorebirds Nesting sites for spotted sand piper Winter habitat for purple sandpiper

Functions and Values of Salt Marsh:

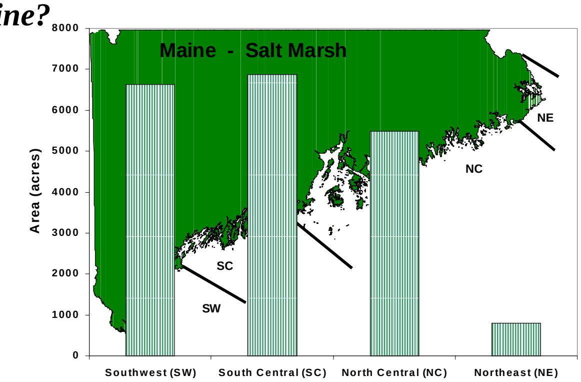
What is Salt Marsh?

Salt marshes are one of the most productive habitats on earth (Kneib 1997). Salt marshes are persistent marine nearshore emergent grass habitats. They lie between the upland and intertidal flats and beaches in protected bays and coves, along tidal rivers or behind barrier beaches. Marshes can exist at the same location for up to 4,000 years. The salinity ranges between 0.5 - 34 parts per thousand (ppt). Marshes occur in low energy habitats with sources of fine grained sediments. Tidal marsh plants, marine and terrestrial plants and algae decompose and combine with mineral sediments to form large salt marsh peat deposits (Bryan et al. 1997).

There are three major types of salt marsh: back-barrier marshes, finger marshes and fringe marshes. Each type may contain a variety of marsh types from low marsh, dominated by cordgrass (*Spartina alterniflora*) to high marsh, dominated by salt meadow grass (*Spartina patens*) and black grass (*Juncus gerardii*). Low marsh is flooded by salt water twice daily while high marsh is only flooded irregularly by spring tides. Back-barrier marshes, like the Wells or Popham Beach marshes, are large high marshes located inland of a barrier beach. Finger marshes, border tidal channels and rivers, and fringe marshes are small patchy marshes dominated by low marsh flora on river banks and on upper shores of coastal flats (Bryan et al. 1997).

Where is Salt Marsh Located in Maine?

Statewide there are 19,778 acres of salt marsh on the mainland and offshore islands of Maine. Like sand beaches, most of the expansive high salt marshes are located in southern Maine. Approximately 13,500 acres or 68 % of the total acreage are located south of Penobscot Bay. Fifty percent of the intertidal area south of Portland is composed of salt marsh.



A majority of the larger marshes can be found between Wells and Cape Elizabeth and behind Popham and Seawall Beach in Phippsburg. In comparison, less than 8 % of the intertidal area north of Penobscot Bay is comprised of salt marsh. The eastern salt marshes occur in small fringing patches along river mouths and protected bays and coves. Significant salt marshes border estuaries like the Pleasant River in Washington County.

What are the Functions of Salt Marsh?

Salt marshes have myriad biological, chemical, and geological functions in marine systems. Tidal marshes in the summer are great primary producers converting nutrients into vascular plant growth and diatom mats. Salt marshes produce oxygen. The tall plant canopies provide food and shelter for terrestrial birds and shorebirds, shellfish, and invertebrates. During high tide, they are feeding grounds for mummichog**,** stickleback, killifish, tomcod, Atlantic silversides, cunner, rock gunnel, sand lance and other important forage fish. They are nursery areas for shellfish, insects and other invertebrates. Large populations of flying insects like mosquitoes breed in marshes providing vital food resources for birds and fish. Plants provide structure for the settlement and proliferation of epiphytes. Marsh plants trap and bind marine and terrestrial sediments increasing shoreline elevation and buffering the upland from coastal erosion caused by sea level rise and periodic storm events. The salt marsh absorbs flood waters reducing storm damage in the upland. Salt marsh ecosystems, by slowing water movement, improve water quality by filtering out sediments, storm water and other pollutants and storing them in peat deposits. Marsh ecosystems harbor billions of bacteria that break-down dead organic matter and release nutrients into the water column for uptake by plants and algae. In the fall and winter, dead plant matter is exported into the nearshore marine ecosystem fueling intertidal and subtidal food chains (Nixon 1982; Bryan et al. 1997).

The salt marsh in some parts of Maine can support populations of rare plants such as bulrush (*Scirpus cylindricus*), spike rush (*Eleocharis rostellata*), horned pond-weed (*Lannichellia palustis*), water pimpernel (*Samolus parviflorus*), gerardia (*Gerardia maritima*), marsh-elder (*Iva frutescens*), pipewort (*Lilaeopsis chinensis*), and monkey flower (*Mimulus ringens*) (USF&W 1980).

Amphipods, living in the wrack line at the base of the salt marsh, break down plant matter and provide food for migrating and breeding shorebirds, gulls, and terns.

Mammals forage and live within salt marsh vegetation. Marshes are habitat for field mice and screws. Mink, skunk, raccoon, muskrat and weasels forage on mice, eggs, vegetation and shellfish during low tide (Nixon 1982).

Habitat dependent species, such as *Orchestia uhleri* (amphipod), *Melamus bidentatus* (snail) and ribbed mussels (*Gukensia demissa),* are specially adapted to live within cordgrass zones. These species are not found outside of this habitat.

What are the Economic and Recreational Values of Salt Marsh?

The salt marsh supports commercial and recreation fisheries. Shellfish and finfish that feed and mature within salt marshes for a portion of their lives were harvested and landed for $11 million in 1997 (NOAA 1997). American eel, Atlantic herring, alewife, American shad, rainbow smelt, white hake, bluefish, Atlantic mackerel, butterfish, and winter flounder may spend a portion of their lives in tidal marshes (Wells NERR 1998).

Recreationally, the attractive landscape and its associated animal life encourages boating, sport fishing, hunting, canoeing, kayaking, hiking, sightseeing, bird watching and other recreational activities. Sport fish, such as brown trout, brook trout, bluefish and striped bass forage in salt marsh habitat.

Atlantic salmon, an important recreational sport fish, forage in the salt marsh.

Tidal marshes are used as outdoor classrooms for students and nature enthusiasts. Some archeological sites exist on or near salt marshes (Bryan et al. 1997).

What Additional Ecological Uses do Salt Marsh Provide?

Salt marshes are critical staging, foraging and sheltering environments for many different types of birds. Salt marshes contain populations of insects, worms, crabs, bivalves, small fish and other benthic invertebrates that attract predators. They are foraging areas for 21 species of shorebirds, six species of heron, four species of egret, two bitterns, glossy ibis, Canada geese, marsh hawks, sparrows, swallows, swifts, gulls, terns, and other small terrestrial birds and waterfowl (MIF&W 1994; Nixon 1982; USF&W 1980). American Bittern, a species of special concern, use salt marsh. Hawks, owls, osprey and other raptors forage on mammals, fish and insects in salt marsh habitat.

Drier high intertidal portions of the salt marsh are nesting habitat for terns, piping plovers, willet, marsh hawk, short-eared owl, geese, clapper rails, sparrow, gulls, waterfowl, and others (Nixon 1982).

Marshes also function as roosting habitat for 21 species of shorebirds during long fall and spring migrations (USF&W 1980).

How Sensitive is Salt Marsh to Disturbance and Development?

Salt marshes, including fringing salt marshes, are productive and diverse habitats that are classified by DEP as having a high sensitivity to disturbance and development (see Habitat Rankings).

What Are the Threats to Salt Marsh?

- Shading from physical structures: Shading blocks light and reduces growth of salt marsh plants.
- Physical barriers or direct alteration: Any structures (e.g. groin, seawall, dam, culvert, flap gate, bridge, road) or physical alterations (e.g. ditching, fill, draining) within the salt marsh or adjacent to the salt marsh that can change or restrict current, fresh water, or tidal flows or directions; alter salinity or oxidation of soils; disrupt travel corridors for animals; alter drainage, flooding, or elevation of the marsh; increase human activity and disturbance; prevent sediment movement; and restrict dispersal of plants, fish and invertebrates all threaten the survival of the salt marsh. Also, as sea levels rise, physical barriers prevent the intertidal region from extending landward decreasing the acreage of intertidal habitat.
- Physical structures in the upland: Any structure that dams or alters freshwater input from the mainland into a salt marsh ecosystem negatively impacts salt marsh production and success.
- Sediment disposal: Disposal of any sediments or other material smothers plant and animal life.

- Water quality alterations: Any change in the salinity, temperature, turbidity, or physical properties of the water will negatively affect the salt marsh. Pollutants from point and non-point sources can change communities of infauna and epifauna.
- Impoundment of water: Impoundments smother intertidal species and kill marsh plants.
- Invasion of opportunistic plants and animals: Physical alterations of salt marshes can weaken marsh systems and encourage the invasion of exotic and pest plants (e.g. purple loosestrife, common reed (*Phragmites*)) and animals (e.g. rats).

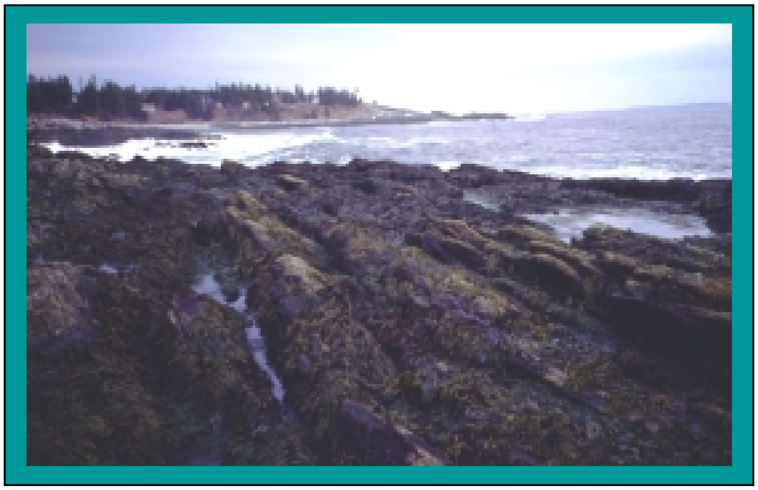
What are the Permitting Issues of Salt Marsh?

- Avoid all activity in, on, over or adjacent to the salt marsh.
- Especially avoid permitting activities that fill, shade, dredge, ditch, or drain the salt marsh. No sediment disposal should be permitted in or adjacent to the salt marsh.
- Water dependent structures (e.g. walkways, piers) should be placed in areas that will not shade the salt marsh in the winter or the summer. If unavoidable, structures should be as narrow as possible, as high as possible and oriented as close to north-south as possible (see guidelines for eelgrass). Don't permit any structure that will lie on the salt marsh. Encourage the joint use of public piers instead of the creation of a new structure.
- For lobster pounds, restrict any activity or impoundment from within at least 25 feet (distance recommendation by NMFS) of the salt marsh.
- Discharges of freshwater or pollutants should be minimized in or around the salt marsh.
- Large machinery should not be allowed on salt marshes.
- Physical barriers should only be permitted in emergency situations. Barriers should minimize the restriction or alterations of current, fresh water, and tidal flows.
- Ditching of salt marshes should not be permitted. Animal travel corridors should not be altered. Sediment movement should not be restricted or enhanced. Human activity and disturbance should be minimized.
- Coastal development on the upland should be restricted. Plan for future sea level rise and allow for ample landward migration of the salt marsh.
- New developments in the adjacent upland should maintain pre-development levels of ground water seepage and eliminate increases of stormwater runoff.
- Disturbance on salt marshes should be avoided during spring and fall shorebird migrations. The fall, due to the migratory flight pattern, is more important than the spring. Spring migration is between mid-April and early June. Fall migration is between July and November (USF&W 1980).

Summary of the Functions and Values of Salt Marsh (adapted from Short, F.T. et al. 1999).

Functions	Values
1. Primary production and seed production	Supports food webs Supports fisheries and wildlife Creates a habitat with high biodiversity
2. Three dimensional canopy structure	Creates habitat Refuge from predation and weather Nursery and larval and egg settlement Supports commercial fisheries
3. Production , accumulation and export of detritus	Fuels microbial, estuarine and offshore food webs Supports commercial fisheries Reduces storm surge and slows shoreline erosion
4. Sediment sink and trap	Improves water quality Supports fishery Lessens coastal erosion
5. Secondary production	Support of food webs Supports commercial fisheries and wildlife Supports terrestrial mammals and birds, waterfowl, wading birds and shorebirds
6. Recycling of nutrients	Supports plant and algal growth Supports commercial fisheries
7. Rare plant and animal habitat	Supports endangered species of Piping plover Supports endangered and threaten plant species
8. Nutrient and contaminant filtration	Improves water quality Supports commercial fisheries
9. Dampens current and wave energy	Prevents upland erosion Minimizes flood damage Reduces resuspension of sediments Increases sedimentation
10. Self-sustaining ecosystem	Encourages recreational and educational activities High aesthetic value / attracts tourists Landscape level biodiversity

Functions and Values of Ledge:

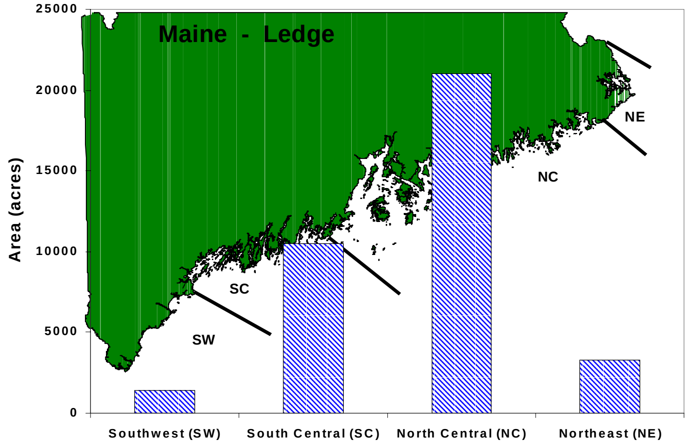


What is Ledge?

Intertidal ledge is bedrock that is exposed to ocean waves, tidal currents, ice, rain and solar radiation. Ancient ledge is either volcanic rock or metamorphic rock, a softer rock scoured out by past glaciations and prone to slow erosion by waves or weathering (Kelley et al. 1989). Granitic headlands, resistant to erosion, form the edge of the eastern seaboard and protect beaches and estuaries from severe ocean swells. Bedrock is a stable permanent structure that allows intertidal plants and animals to attach and colonize substrates. Ledge features approximately four zones of plants and animals tolerant of different levels of predation pressure, tidal exposure and other physical and biological factors. The high intertidal zone, barnacle zone, rockweed zone, and Irish moss zone are usually present on exposed shores. Bedrock contains depressions, cracks and crevices that create tidepools and sheltered habitats as the tide recedes from the shore. Some ledge habitats have boulders at their base.

Where is Ledge Located in Maine?

Ledge is the second most common intertidal habitat in Maine. There are 36,243 acres of rock ledge on the coastline of Maine. Thirty-five percent of this habitat is on offshore islands. A majority of the ledge habitat is located in the central and eastern portions of the state. Only 4 % of rocky shores is found south of Cape Elizabeth. Almost 60 % of the ledge in Maine is located in the "island-bay complex" (Kelley et al. 1989) between Penobscot Bay and Machias Bay.



What are the Functions of Ledge?

Ledge habitats have different ecological functions based on their exposure to wave energy and their location within the intertidal zone. Ledge supports populations of animals specially adapted to survive battering by high energy surf. In general, exposed sites have the greatest bio-diversity of macroalgae and invertebrates. Yet, sites that are too exposed to pounding surf have fewer species due to damage and removal of organisms by powerful waves. Diversity and productivity on rocky shores increases as you move from the high intertidal to the subtidal.

Rocky shores are one of the most diverse and productive intertidal habitats (USF&W 1980 Ch 4). Rocky shores support populations of suspension feeders (e.g.mussels, barnacles, sponges), grazers and herbivores (e.g. sea urchins, limpets, snails), predators (e.g. rock crabs, dog winkles, blood stars, sea stars, nudibranchs), carnivores (e.g. anemones) and scavangers (e.g. amphipods). Ledges are attachment sites for rockweeds, kelps, other macroalgae and Irish moss (see kelp and rockweed). Irish moss provides attachment sites for plants and animals; primary food for invertebrates and fish; shelter for marine life from wave and wind exposure, temperature extremes, ice scour, dessication, and other physical factors; and nursery areas for invertebrates and fish. Tidepools, within basins of the ledge, offer a refuge from extremes in temperature and salinity for a rich assemblage of plants, invertebrates and fish. Tidepools provide habitat for brittlestars, amphipods, scaleworms, sea urchins, arctic clams, chitons, limpets, sea stars, snails, lumpfish, rock gunnel, sticklebacks, sculpins, seasnails, grubby, cunners, anemones, sponges, hermit crabs, nudibrachs, tunicates, and worms (Brown 1993). Downeast spider crabs and sea spiders are found living in tide pools. Crevices and cracks in the bedrock are settled by numerous species that can only survive in sheltered habitats.

Sea-birds (e.g. oldsquaw, common eider, black scoter), loons, herring and black-backed gulls, at least 9 species of shorebirds, waterfowl, cormorants, osprey and ducks (e.g. mergansers, loons, golden-eyes, harlequin ducks) prey on snails, mussels, fish, amphipods and other invertebrates on rocky shores (Mathieson et al. 1991; Brown 1993; USF&W 1980). Ledges are foraging sites for mink and terrestrial birds. Bedrock on outer islands of Casco Bay provide wintering habitats for scoters, eiders and old squaw ducks and are utilized by brant in the spring (USF&W 1980).

Ledge functions as roosting habitat during seasonal migrations for 14 species of shorebirds (USF&W 1980).

Ledges surrounding islands and isolated mainland headlands are foraging habitats and haulout, breeding, and pupping sites for gray and harbor seals (USF&W 1980).

Upper shores of ledge habitats with sediment deposits support populations of rare plants (USF&W 1980).

Bald eagles and ospreys nest and feed near ledge habitats (Brown 1993).

Ledges are wintering habitat for purple sandpipers (USF&W 1980).

What are the Economic and Recreational Values of Ledge?

Ledges function as a nursery area, foraging habitat and attachment site for commercial species of invertebrates and fish valued at over $164 million in 1997 (NOAA 1997). It is an important settling, nursery and foraging area for lobsters, sea urchins, blue mussels, and periwinkles. Juvenile pollock, in the summer time, feed during high tide day and night on amphipods, periwinkles, mussels and isopods on vegetated rocky shores (Rangeley and Kramer 1995). Kelp, rockweed, Irish moss and dulse are harvested from rocky shores. Rock gunnel and other small fish live on ledge and feed adult cod and pollock. Tidepools are used as foraging areas during high tide by winter flounder and pollock (Brown 1993).

Rocky shores are foraging areas for striped bass, an important recreational fishery in Maine.

How Sensitive is Ledge to Disturbance and Development?

Ledge habitats have three levels of DEP classifications based on their location in the intertidal zone (see Habitat Rankings). Low intertidal zones of ledge with algae are classified as highly sensitive to disturbance because they are very diverse productive habitats supporting populations of algae and animals restricted to this environment. Low intertidal species can not tolerate disturbance, salinity changes, desiccation, or pollution. Mid-intertidal zones with algae are classified as moderately sensitive to disturbance. Mid and high intertidal zones without algae are inhospitable environments and are therefore classified as low sensitivity habitats.

What are the Threats to Ledge?

- <u>Shading from physical structures</u>: Shading blocks light and reduces algal growth.
- <u>Removal of habitat</u>: Blasting of ledge or placement of structures removes habitat and animal communities.
- <u>Pollution</u>: Run-off of sediments and pollutants from upland construction sites, increases in freshwater discharge, industrial discharges, oil pollution, stormwater run-off, sewage, airborne pesticides from agriculture and others all damage ledge communities.
- <u>Resuspension of sediments</u>: Resuspention of sediments from nearby dredging, filling, boating and fishing activity smother animals on ledge.

What are the Permitting Issues of Ledge?

- Avoid permitting activities that remove habitat and/or threaten algal or marsh communities on ledge.
- Permit activities in mid and high intertidal zones without vegetation; avoid any activity in low intertidal or shallow subtidal zones.
- Water dependent structures should be place in areas that will not shade algae or indirectly impact algal beds on ledge. If unavoidable, structures should be as narrow as possible, as high as possible and oriented as close to north-south as possible (see eelgrass for guidelines). Avoid permitting activities where boat traffic can shade or scour beds.
- If applicable, determine if current velocity, tidal flows, wave energy or water clarity will be altered due to the proposed activity. If so, design project to minimize physical changes.
- Discharges of freshwater or pollutants should be minimized around ledge habitats.
- New developments in the adjacent upland should maintain pre-development levels of ground water seepage and eliminate increases of storm water runoff.

Summary of the Functions and Values of Intertidal Ledge Habitats.

Functions	Values
1. Production of animals on rocks, in tide pools, on and within algal beds	Supports commercial fisheries Supports the food web Supports recreational sport fishery Support shorebirds, seabirds, and sea ducks Support terrestrial mammals Supports bald eagles, osprey and harbor seals
2. Permanent and stable attachment sites for primary producers (see kelp / rockweed)	Food resources for consumers Support commercial fisheries and wildlife Commercially harvested for food and nutrients
3. Roosting sites and wintering habitat for birds and haulouts for mammals	Helps sustain healthy populations of shorebirds, sea birds, sea ducks, brant, gray and harbor seals
4. Intercepts and slows currents and waves	Reduces shoreline erosion of nearshore habitats Increases sedimentation Enables formation of protected soft bottom habitats
5. Nursery and spawning ground	Helps sustains commercial fishery populations Maintains balanced ecosystem
6. Nutrient and contaminant filtration	Improves water quality Supports commercial fisheries
7. Rare plant and animal habitat	Supports bald eagles Supports rare plant species on upper ledges
8. Oxygen production	Provides oxygen for marine organisms Improves water quality Supports commercial fisheries
9. Production, accumulation and export of detritus	Fuels microbial, estuarine and offshore food webs Supports commercial fisheries
10. Recycling of nutrients	Supports plant and algal growth Supports commercial fisheries
11. Self-sustaining ecosystem	Increases marine biodiversity Forms numerous and complex microhabitats Supports movie and tourism industry

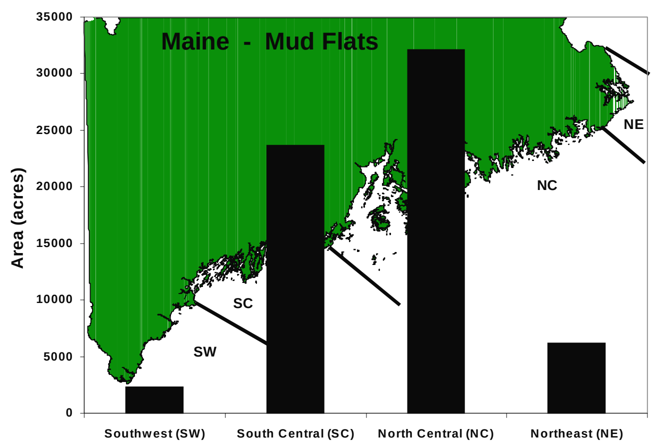
Functions and Values of Mud Flats:

What are Mud Flats?

Intertidal mud flats are low energy protected environments that are ecologically and commercially important habitats in Maine. Sediments are composed of fine clays, silt, sand and organic matter. Sediments are supplied to the mud flat from the terrestrial environment by rivers and streams, landslides and adjacent eroding coastal bluffs and margins of bays (Kelley et al. 1989). Sediments are constantly redistributed by tidal action and wind generated waves and currents. Anoxic sediments, black colored mud depleted in oxygen, usually are present below the surface (1/2 - 2 cm depending on total organic carbon). Gray colored sediments below anoxic sediments indicate the presence of iron pyrite (Whitlatch 1982)

Where are Mud Flats Located in Maine?

In Maine, there are approximately 64,300 acres of mud flats totaling 44 % of all coastal intertidal environments. They predominately occur in protected bays, coves, inlets and estuaries. The majority is north of South Portland, with the highest concentration (60 %) located north of Port Clyde. Only 4 % of all mud flats in Maine is found south of Cape Elizabeth.



What are the Functions of Mud Flats?

Mud flats are organically rich regions that support large populations of shellfish, shrimp, mussels, quahogs, baitworms, and small invertebrates (Larson and Doggett 1991). By slowing tidal and wave energy, mud flats buffer the upland against tidal erosion and lessen impacts from storm surge events. Eelgrass beds and macroalgae, that add structure to the habitat, cover many flats in Maine (see photo). Sediments contain high concentrations of benthic diatoms that form the base of the benthic food web, remove nutrients from the mud, and lessen erosion by binding sediments. Small fish like mummichogs and sticklebacks forage on invertebrates and algae during flood and ebb tide (Whitlatch 1982). Flats support high concentrations of bacteria, fungi, and other microorganisms that contribute to nutrient cycling and provide food for larger macrofauna like sand worms. They are limited resources that perform a vital function as sinks for contaminants.

Mud flats are critical feeding grounds for 25 species of migrating and resident shorebirds, six species of herons, two species of egrets, glossy ibis, Canada geese, commercial and non-commercial finfish, herring gulls and waterfowl (USF&W 1980). Flats are nursery grounds for winter flounder and other flatfish. They provided roosting and staging areas for migrating shorebirds (USF&W 1980; Larsen and Doggett 1991).

Mud flats are potential habitat for the rare plant pipewort (*Eriocaulon parkeri*)(USF&W 1980).

What are the Economic Values of Mud Flats?

Mud flats contribute to a multi-million dollar seafood industry in Maine by providing structure and foraging habitat for soft-shell clams, Atlantic herring, blood worms, blue mussels, sand worms, periwinkles, alewife, winter flounder, rainbow smelt, Atlantic mackerel and sand shrimp (Brown 1993; Whitlatch 1982).

How Sensitive are Mud Flats to Disturbance and Development?

Mud flats are low energy protected and productive environments that are classified by DEP as highly sensitive to anthropogenic influence (see Habitat Rankings). They are the most sensitive marine habitat to perturbations (Larsen and Doggett 1981). Mud flats are protected from heavy wave and current action. Therefore, flushing is limited, causing flats to recover slowly from physical disturbances and pollutants to concentrate. Contaminants can accumulate in the fine sand and clay particles, building up to toxic levels.

What are the Threats to Mud Flats?

- Filling of mud flats: Filling results in a direct loss of intertidal habitat.
- Dredging, dragging or other major physical disturbances: Disturbances liberate toxics and nutrients from sediments into the water column. Dredging removes habitat that can lead to increases in coastal erosion. Dragging kills epifauna and encourages the spread of opportunistic species.
- Sediment disposal: Disposal of any sediments or other material smothers plant and animal life.
- Seawalls and other shoreline stabilization barriers (e.g. riprap): Mud flats require continual sources of sediments from upland and coastal erosion. Without renewable

resources of fine grain sediments entering these regions, surface layers of mud flats will erode leaving behind hard clays and altering the species composition and productivity of the flat. As sea levels rise, physical barriers prevent the intertidal region from extending landward thus decreasing the acreage of intertidal habitat.

- Water quality alterations: Any change in the salinity, temperature, turbidity, or physical properties of the water will negatively affect mud flats. Pollutants from point and non-point sources can change communities of infauna and epifauna.
- Lobster pound creation / Impoundment of water: Lobster pounds convert intertidal areas into subtidal areas by changing the hydrologic system. This leads to the loss of fine sediments and rockweed, and a reduction in species diversity within the benthic and algal communities.
- Other physical barriers: Any structures (e.g. groin, dam, culverts, bridge) that change current or tidal flows or directions, alter salinity, disrupt travel corridors for animals, modify drainage of flats, prevent sediment movement and larval and fish passage threaten the survival of mud flats.
- Pipe laying: Laying of pipe leads to the loss of habitat under the pipe and the potential impact from any waste discharged from the pipe.

What are the Permitting Issues of Mud Flats?

- Shoreline development, discharges of freshwater or pollutants, or disturbance should be minimized in or around mud flats. No filling of flats should be permitted without proper compensation. Large machinery should not be allowed on mud flats.
- Dredging should be avoided or managed in a careful manner. Chemical sediment analysis, dredge disposal sites and geological processes should be evaluated before permitting any activity.
- Physical barriers should only be permitted in emergency situations. They should never extend into the subtidal.
- Coastal development on the upland should be restricted around flats. Plan for future sea level rise and allow for ample landward migration of mud flats.
- New developments in the adjacent upland should maintain pre-development levels of ground water seepage and eliminate increases of stormwater runoff.
- Disturbance on mud flats should be avoided during spring and fall shorebird migrations. The fall, due to the migratory flight pattern, is more important than the spring. Spring migration is between mid-April and early June. Fall migration is between July and November (USF&W 1980).

Summary of the Functions and Values of Mud Flats (adapted from Short, F.T. et al. 1999).

Functions	Values
1. Production of animals on and within the mud or sand	Supports commercial fisheries Food for fish, crab, shrimp, and other invertebrates Essential food resources for migrating shorebirds Supports the food web
2. Primary production from benthic diatoms and algae	Improves water quality Binds sediments therefore reducing erosion / resuspension Fuels benthic food web Supports commercial fisheries and wildlife
3. Recycing of nutrients by bacteria	Supports plant and algal growth Supports commercial fisheries
4. Sediment sink and trap	Improves water quality (removes nutrients and toxics) Lessens coastal erosion
5. Essential habitat	Provides the soil for eelgrass germination and proliferation Nursery ground for commercially important fish Roosting and staging areas for migrating shorebirds